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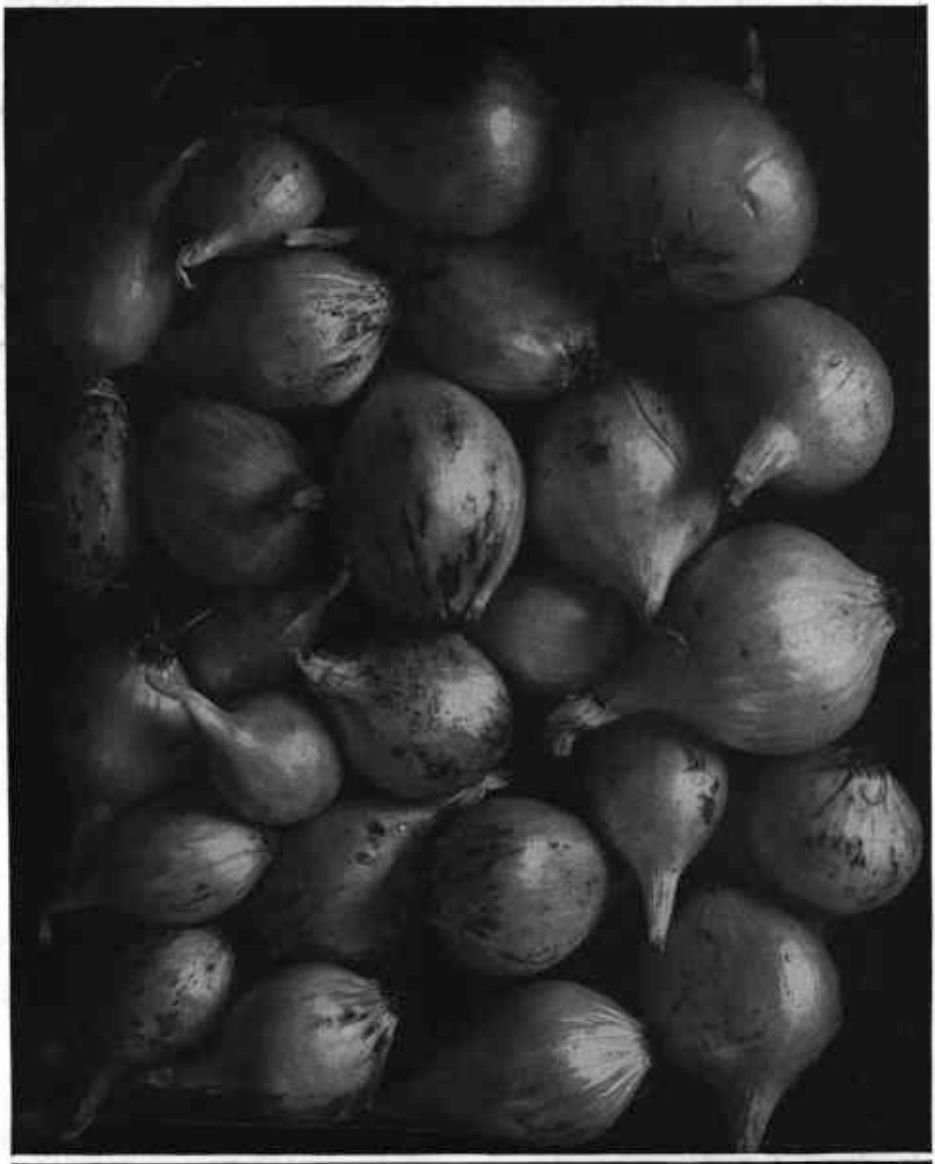
ONION DISEASES and their Control



FARMERS' BULLETIN NO. 1060
U.S. DEPARTMENT OF AGRICULTURE

ONION DISEASES in the field vary in kind and in intensity with the climatic, soil, and other environmental factors in the various sections where onions are grown; diseases of onions in transit and in storage vary with the variety of onions, farm practices, and conditions of storage.

Onion smut, which remains alive in the soil for indefinite periods and is found in the Northern States from coast to coast, can be controlled by formaldehyde drip or by thiram dust applied to the seed with Methocel sticker; but most of the other diseases described are not readily controllable by chemical treatments. To supply consumers with adequate quantities of sound onions, reliance must be placed on crop rotation; timely cultivation; fertile soil; the use of resistant varieties and disease-free bulbs, sets, and seed; sanitation; steam sterilization; and proper methods of handling, curing, and storage, as suggested in this bulletin.

Storage just above 32° F. and at 70 to 75 percent relative humidity is best. In very cold weather it may be necessary to heat the storage house to prevent injury from severe or repeated freezing.

Washington, D. C.

Revised June 1944
Slightly revised October 1959

ONION DISEASES AND THEIR CONTROL

By J. C. WALKER, *collaborator, Crops Research Division, Agricultural Research Service, and professor of plant pathology, University of Wisconsin.*

Contents

IMPORTANCE OF THE ONION INDUSTRY

THE ANNUAL ONION CROP in the United States averaged slightly more than 43 million 50-pound sacks grown on about 127,000 acres from 1945 to 1956, inclusive. Culture of the onion (*Allium cepa* L.) is intensive; the growing of the crop entails heavy investments in land, fertilizer, and labor. Onions are one of the few crops in which repeated cropping or very short rotations are commonly practiced. Individual growing areas are therefore relatively small and concentrated; but they are not limited geographically, since intensive onion-growing districts are to be found in most States. The 10 States leading in total production are New York, Texas, California, Colorado, Michigan, Oregon, Idaho, Utah, Minnesota, and Washington.

Sections producing the crop of table onions may be divided into three groups: (1) Northern States from Massachusetts to the Pacific coast, including northern California, where about 75 percent of the total is grown as a late-summer or fall crop; (2) central California, south-central Washington, and New Mexico, Iowa, Oklahoma, Kentucky, Virginia, and New Jersey, where about 5 percent is grown as an early-summer crop; (3) Southern States extending from southern California to Georgia, where about 20 percent is grown as a spring crop.

In the northern sections most of the crop is grown from seed sown directly in the field in early spring at the rate of 3 to 5 pounds per acre. No thinning of the stand is made. Both upland soils and muck are used, but in recent years the acreage of the crop on muck has increased rapidly until at the present time it comprises the greater part.

The older varieties are Southport Yellow Globe, Early Yellow Globe, Michigan Yellow Globe, Southport White Globe, Southport Red Globe, Mountain Danvers, and Yellow Globe Danvers in the East and Midwest; additional varieties such as Australian Brown are grown in California. Several newer hybrid varieties are now in use.

In the Rocky Mountain sections on irrigated alluvial soils the Sweet Spanish varieties are grown extensively. In the early-summer-producing sections some of the acreage is grown from sets; flat varieties such as Ebenezer, Red Wethersfield, and White Portugal and the globe-shaped variety Early Yellow Globe are so grown. Most of the northern crop is carried in storage for various periods and is placed on the consuming market throughout the country up to March and April.

Most of the spring and some of the early-summer crop is of the very flat, mild-flavored Bermuda type, chiefly Yellow Bermuda, Crystal Wax, and several new hybrid varieties. Globe varieties of the Denia class are grown less extensively. The seed is sown in late summer and early fall in seedbeds, whence plants are set during the mid-winter months. Much of the acreage is under irrigation. The crop matures in April and May. These southern crops thus supply the consuming markets throughout the country during April, May, June, and July. The Bermuda type is not adapted to long storage, and the marketing season of this crop is thus much shorter than that of the northern crop.

Onion sets are chiefly of the Red Wethersfield, Ebenezer, and White Portugal varieties. They are grown in several Northern States, always on upland or alluvial soil. The majority are produced in the Chicago section, extending from northwestern Indiana through northeastern Illinois and southeastern Wisconsin, and less extensively in the Greeley, Colo., district. The seed is sown in early spring, as are table onions, but at the rate of 75 to 80 pounds of seed per acre.

Some of the crop is shipped south immediately after harvest for fall planting; most of it is stored, however, and shipped during the winter and throughout the spring. Onion sets are widely distributed and used generally for spring bunching onions in the home garden and on the commercial truck farm.

Onion seed is grown chiefly in the Western States under irrigation where dry summer weather facilitates pollination, harvesting, and curing of the seed.

Several close relatives of the common bulb onion are mentioned here because some of them are affected with the usual onion diseases. The Egyptian onion (*Allium cepa* var. *viviparum* Metz.) belongs to the same species. It is hardy in the Northern States; its culture is confined largely to home gardens, where it provides an early supply of green onions. Being hardy, it continues as a perennial crop. Edible bulbs are not formed, but during the summer stems similar to seed stems are produced; at the top of these, bulblets, known as top sets, are produced. The top sets are used for the starting of new beds. The relatively uncommon multiplier onion (*A. cepa* var. *solaninum* Alef.) has dividing bulbs. Garlic (*A. sativum* L.), propagated from bulbs, is produced commercially in California, Texas, and Louisiana. Leek (*A. porrum* L.) is a flat-leaved relative, propagated from seed. Shallots (*A. ascalonicum* L.), propagated from small bulbs, are grown commercially as a winter crop in Louisiana, where they are marketed as bunched green onions. The Welsh onion (*A. fistulosum*

L.) is propagated from seed, and each plant produces a group of several scallions. It does not produce a distinct bulb but may be used as a source of bunched onions. Chive (*A. schoenoprasum* L.) is an onion relative, which is propagated vegetatively in greenhouses or out-of-doors for use as a garnish.

It may be seen from this brief survey that the crops of onions and of onion relatives are grown under a variety of climatic conditions and on a wide range of soils. As environmental factors have a direct bearing upon disease, the preeminent diseases vary with geography. In the discussion of the diseases, reference will be made repeatedly to specific growing sections and cultural practices.

DESCRIPTIVE KEY TO ONION DISEASES

The following key to the outstanding symptoms of onion diseases will aid in their recognition. In some cases the sections where the disease is apt to be most common or severe are given to help in the identification.

A. Diseases Important in the Field:

1. Dark pustules within the leaves or scales, sometimes splitting open later and exposing black powdery masses; principally on young seedlings (fig. 1). (Northern States.)---------- **Smut** (p. 4)
2. Rapid death of very young seedlings in circular patches in the field. **Damping-off** (p. 8)
3. The leaves, beginning at the tips, turning pale green and later yellowish, becoming covered with a violet furry growth, and finally collapsing; most serious in moist weather in midseason or later (fig. 6). (Most onion-growing States; severe in California, New York, Oregon, and Michigan.)---------- **Downy mildew** (p. 8)
4. Black moldy growth on leaf tips or seed stems, often following downy mildew or purple blotch---------- **Leaf mold** (p. 10)
5. Large purplish lesions, sometimes showing zonation, eventually girdling leaves and seed stems---------- **Purple blotch** (p. 11)
6. Rapid dying back from the tips of the leaves, accompanied by a rot starting at the base of the bulb (fig. 7). (Northern States; Rocky Mountain irrigated valleys.)---------- **Fusarium rot** (p. 12)
7. Dying of the tops rather similar to that in fusarium rot, but differing from it in that round black bodies about the size of poppy seeds appear in the diseased bulb (fig. 8). (Southern States.)--- **White rot** (p. 13)
8. Roots turning pink, shriveling, and dying; new roots attacked and a marked stunting of the plant resulting---------- **Pink root** (p. 11)
9. Orange or golden-yellow pustules on leaves or seed stems, especially on those of the Egyptian onion; rare---------- **Rusts** (p. 13)
10. Pronounced stunting accompanied by various degrees of yellowing. **Yellow dwarf** (p. 14)
11. Killing of the tops in roughly circular areas in the field by creeping or twining leafless plants attacking leaves (fig. 10). (California, Washington, Illinois, and elsewhere.)---------- **Dodder injury** (p. 16)
12. Leaves becoming sickly green; swellings forming on the roots (fig. 11). (Southern States.)---------- **Root knot** (p. 17)
13. Distorted growth of young plants; flaccid leaves of older plants; soft mealy appearance of bulb scales. (New York.) **Eelworm rot, or bloat** (p. 17)
14. Flower cluster of seed plants developing abnormally long pedicels, to which flowers are attached; flower parts distorted and flowers sterile (fig. 9). (Idaho, Wisconsin, and perhaps elsewhere.) **Aster yellows** (p. 15)

B. Diseases Important in Storage and Transit:

1. Rot usually beginning at the neck of the bulb and progressing downward; tissues shrinking and collapsing; a gray to brown moldy growth and hard black kernels appearing later on the surface of affected scales (figs. 12 and 13)---------- **Neck rot** (p. 20)

B. Diseases Important in Storage and Transit—Continued

2. Rot beginning at harvesttime or later, but differing from neck rot in being softer and more watery, usually with a very offensive odor (fig. 14). **Bacterial soft rot** (p. 21)
3. A semiwatery rot advancing from the base of the scales upward (fig. 7). **Fusarium rot** (p. 12)
4. Black powdery masses, not in definite pustules within the scales, as in smut, but on the outer surface of the scales or between them (fig. 15). **Black mold** (p. 22)
5. Smudgy, superficial, dark-green to black spots made up of fine dots, but with no powdery masses, appearing shortly before harvesttime on the outer scales; primarily on white varieties (fig. 16)---- **Smudge** (p. 23)
6. Semiwatery decay, at first deep yellow, then wine red, and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture---------- **Purple blotch** (p. 11)
7. Silvery-gray to black discoloration of dry outer scales of Texas-grown Crystal Wax onions-----**Diplodia rot** (p. 24)
8. Dry decay of garlic, with brown kernel-like bodies in and on decayed tissue---------- **Aspergillus rot** (p. 24)
9. Light-yellowish lesions on fleshy scales of onions; later, with a fine, white surface mold; conversion of garlic cloves to greenish-tan or gray powdery mass---- **Blue mold rot** (p. 25)

Figure 1.—A half-grown onion plant showing in the scales and leaves brown to black unbroken blisters, or pustules, caused by smut. When the blisters break open, the black powdery masses of spores of the smut fungus are exposed.

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Smut is a disease caused by a fungus which remains viable in the soil for many years. Smut-infested soil is therefore likely to remain infested indefinitely and is found usually in areas where onions have been grown intensively for a long time. This disease is to be found in many onion sections in the Northern States from coast to coast. It is not a factor in the winter-growing southern sections; its almost complete absence is due largely to climatic conditions. Leek is also affected.

Characteristics

The disease appears soon after the seedlings emerge above ground. Brown to black elongated blisters form within the scales or leaves; the latter usually are slightly thickened and often curved downward abnormally. These blisters often break open and expose black powdery

masses made up of the spores of the causal fungus. A majority of the infected seedlings die within 3 to 5 weeks after germination. Such thinning of the stand is thus an early and important feature of smut injury, although a small percentage of infected seedlings outgrow the disease. Some diseased plants survive until midseason or harvest, new leaves and scales becoming infected as they develop. Figure 1 shows a half-grown infected plant which has survived the seedling stage. Such plants usually produce bulbs so small and imperfect that they are thrown out at harvest.

Occasionally, infected bulbs are large enough and so slightly affected as to escape notice and reach the warehouse and market. Such specimens are characterized by slightly raised brown to black pustules most prevalent near the base of the outer fleshy scale and occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

Causal Organism

The fungus parasite (*Urocystis cepulae* Frost) associated with onion smut infects only the onion and certain closely related species of plants, such as leek. Most varieties of the Welsh onion are resistant to this disease. The black powdery masses exposed upon the splitting of the blisters, or pustules, in the onion leaf consist of myriads of spores, or seed bodies, which propagate the fungus. These spores are highly resistant to environmental changes; as they become incorporated in the soil, they remain viable for many years. This is the reason that continuous cropping is favorable to the accumulation of the fungus and that soil once infested remains so indefinitely.

The spores germinate by sending out fungus threads, which permeate the soil and often break up into many secondary spores. These stages of the fungus are sensitive to cold and drought and survive for short periods only. The threads penetrate young onion seedlings, take nourishment from the plant, and form the characteristic blisters within the tissue; finally more dark spores develop.

Important to the understanding of onion smut and its control is the fact that the fungus can invade the onion plant only in the early seedling stage. If the outer seedling leaf (cotyledon) escapes infection until it is mature (about 3 weeks from germination), no further invasion occurs even in very heavily infested soil. This is the reason why smut is not a disease factor when the crop is started from sets or transplants, even though they are set in smutty land. When the mean soil temperature is 84° F. or above during the period of the seedlings' susceptibility, no infection occurs, because the fungus is inactive at this high temperature. At slightly lower temperatures the seedlings tend to outgrow the disease more effectively than in cool soil. These temperature relations explain the absence of the disease on the southern onion crops, where the seed is sown in late summer. The seedlings are thus started off in very warm soil, which is unfavorable to smut. In the main crop of the Northern States the seedlings come up in cool soil, and the smut fungus, if present, is not inhibited.

Smut spores are spread locally by farm implements, by the feet of men and animals, by surface drainage water, and by air-borne soil. The transfer from locality to locality is rarely made through the medium of seed, but commonly by means of onion sets grown on smutty soil.

As just stated, the crop started with sets or transplants is not affected. In the main crop of the North, started from seed in the field, the disease is controlled by the formaldehyde-drip method. This consists of the application of a stream of dilute formaldehyde in the furrow with the seed. The vapor of the formaldehyde permeates the soil in the area between the seed and the soil surface sufficiently to disinfect it temporarily insofar as smut is concerned. The young seedling is thus protected during its susceptible period. The effectiveness of the treatment is sometimes reduced if heavy rain follows immediately after sowing; however, a lapse of 24 hours without rain usually insures successful control.

Formaldehyde-drip attachments on a single-row seeder and on a gang seeder are shown in figures 2 and 3. The effect of the treatment on stand and yield is shown in figures 4 and 5. The treated rows in one field averaged 545 bushels per acre and the untreated ones 200 bushels.

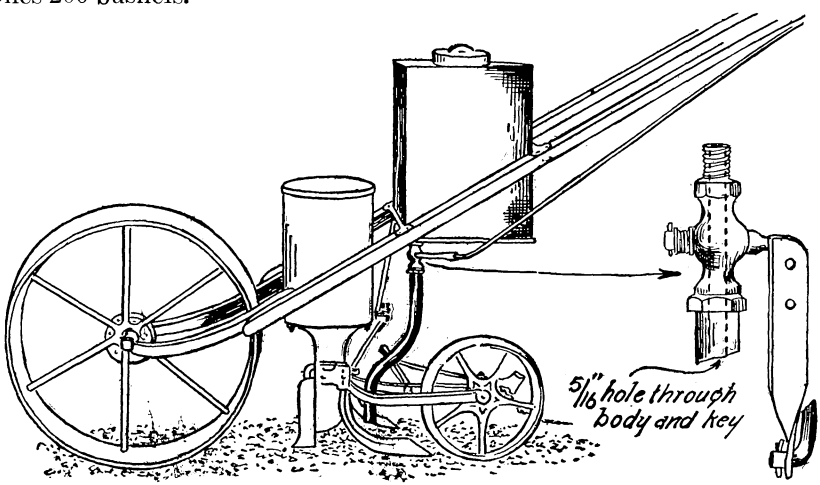


Figure 2.—A single-row onion seeder equipped with a formaldehyde-drip attachment for control of onion smut. Note that the disinfectant is introduced into the furrow just after the seed is dropped and before the furrow is covered. The cut-off valve is regulated from the handle of the seeder.

There is some latitude in the strength of the formaldehyde solution and the rate of application. When 14-inch rows are planted, the best results have been obtained with a solution made from 1 pint of concentrated formaldehyde (37- to 40-percent) to 16 gallons of water, applied at the rate of 200 gallons per acre. Almost as effective results were obtained with a solution of 1 pint to 8 gallons of water, applied at the rate of 100 gallons per acre. The second formula is now more commonly used.

As formaldehyde is irritating to the skin, it should be handled with care.

Another method of smut control has been devised; it consists of applying a dust fungicide to the seed. Thiram is the most satisfactory material. It is used as a protectant for many types of seeds to prevent seed decay by soil organisms and the resulting poor stands. When it is applied to onion seed in the amount usually used for seed

Figure 3.—A six-row seeder equipped with a formaldehyde-drip attachment for the control of onion smut.

Figure 4.—Onions growing on smut-infested soil most of which was treated with formaldehyde. Note that most of the plants in the two untreated rows in the center are dead and that in the treated parts of the field there is practically a full stand.

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Figure 5.—Yields of a treated (left) and of an untreated (right) row of onions in the field shown in figure 4.

protection (1 ounce to 10 pounds of seed), there is little or no effect upon smut. It is necessary to use much more dust for control of smut. One pound of thiram to 10 pounds of onion seed has given fairly satisfactory results even though all the dust does not adhere to the seed and uneven distribution results. Better distribution is obtained by applying Methocel sticker to the seed first, but then more dust is needed. One ounce of 4-percent Methocel solution is applied to 10 pounds of seed and mixed thoroughly; 2½ pounds of thiram is then added; the seeds are agitated in a butter churn or similar device until they are well and uniformly pelleted with the dust. The rate of seeding should be adjusted to allow for the greater size of pelleted seeds. The thiram treatment has been shown to be about as effective as formaldehyde. The cost of material is somewhat greater than that of formaldehyde, but the ease of application offsets that disadvantage. Growers whose soil is infested with smut and who are not equipped to apply formaldehyde should use the dust treatment.

DAMPING-OFF

Damping-off is a disease common to seedlings of many plants. One or more of several soil fungi may be involved. When seedlings are growing rapidly they are subject to attack by these fungi, whereas at other times they are resistant. The plants are attacked at the soil line or slightly below, and the tissue shrinks rapidly while the still turgid above-ground parts topple over. Damping-off in onions does not ordinarily take the form of thinning out plants here and there, but more often it kills practically all plants in roughly circular areas of various sizes.

There is no specific remedy for this disease. The best cultural practices, such as frequent cultivation, good drainage, and good fertility, all discourage damping-off by providing the most favorable growing conditions for the onion plant. Treatment of the seed with Semesan or thiram dust, according to directions given by the manufacturer, may be helpful but not necessarily so. It has no value if the formaldehyde-drip treatment is to be applied at sowing to control smut.

As mercury is poisonous, Semesan should be handled carefully and stored out of the reach of animals and children.

DOWNY MILDEW

Downy mildew has been reported from most States where onions are grown. Its destructiveness varies widely with locality and season. Relatively cool, moist weather is most favorable for its development. Losses are most severe on the bulb crop in New York, Oregon, and Michigan. In California losses in the seed crop during the winter and

spring are sometimes heavy, since the foggy weather is especially favorable to the mildew; it attacks the seed stems and causes them to fall over before the seed is mature.

Characteristics

The first symptoms are found most readily by examining leaves closely in the early morning while the dew is still present. The violet furry growth on the surface of the leaf or seed stem is characteristic. The affected leaves gradually become pale green and later yellowish, and the diseased parts collapse. The furry growth becomes more widespread if the humidity remains high, but the advance and spread are very dependent on favorable weather. The disease commonly starts in spots in the field and spreads to surrounding areas. If the weather remains dry after an outbreak, plants send out new leaves and partially recover; but on the return of humid conditions the fungus revives and the new growth becomes blighted. Repeated killing of leaves in this manner reduces growth, and the bulbs remain small while the necks are unduly succulent and subject to attack by storage-decay organisms. Lesions on seed stems are circular or elongate, often affecting only one side of the stalk; they weaken the stalk and cause it to break over from the weight of the seed umbel. This causes shriveling of the seeds. The fungus may infect the flower parts as well, and there is circumstantial evidence that it is carried with the seed.

Figure 6.—Onion plant affected with downy mildew. The furry growth on the dying, older leaves consists of fruiting branches of the causal fungus and many thin-walled, light, microscopic spores, which are readily disseminated by the wind.

Causal Organism

The causal organism (*Peronospora destructor* (Berk.) Casp.) is closely related to those associated with potato late blight, grape downy mildew, and cucumber downy mildew. The onion fungus is confined largely to onion, Welsh onion, and chives. Garlic and leek have been reported as hosts, but it is not certain that they are subject to infection by the same strain of the fungus as that which affects the onion. The furry masses (fig. 6) on the affected parts of the plant are made up of branches of the fungus which extend above the surface and bear numerous microscopic spores. These spores are thin-walled and light; they are easily detached and transported by air currents, and this is the chief means whereby the fungus is disseminated locally. They are short-lived, however, and very sensitive to drying. If moist weather, favorable

to infection. does not prevail, most of them die without causing infection.

When damp weather prevails, the spores germinate promptly. If germination occurs on the leaf surface, the germ tube growing into a thread enters through a breathing pore (stomate) into the internal tissue. As the fungus absorbs food from the onion the cells of the latter gradually succumb; as a result the leaves turn yellow, shrivel, and die. The fungus sends fruiting branches to the surface, where they produce more spores.

Another type of spore, the resting spore (oospore), is formed in the dying plant tissues. Because this spore has a thick wall and a concentrated food supply, it is suited to withstand unfavorable environment. The internal threads (mycelium) also survive for long periods, especially when they get into the bulb before it matures. Oospores and mycelium may be carried with the seed, but the evidence that seed is an important carrier of the organism is very meager. Thus, the fungus lives over unfavorable periods chiefly as oospores or as mycelium in bulbs and sets and may be transported long distances in this way. In some places, as in New York, the perennial Egyptian winter onion in home gardens serves as an overwintering source of the fungus.

Control

Although many other downy mildews, such as grape downy mildew and potato late blight, are successfully controlled by spraying with bordeaux mixture, this has not proved to be the case with onion downy mildew. One reason is the great difficulty in obtaining thorough coverage of the very waxy foliage. A second reason is the continual emergence of new leaves from the neck, necessitating very frequent applications for complete protection. In California encouraging experimental results have been obtained with sprays consisting of (1) cuprous oxide plus rosin soap, (2) rosin lime-sulfur, and (3) bordeaux mixture plus cottonseed oil. Zineb also is used satisfactorily.

In districts where downy mildew occurs frequently cultural practices are about all that can be applied to reduce losses, and these are not wholly effective. Burning refuse to reduce the carryover of the resting spores and mycelium may be advisable. Onions should not be planted in fields with poor air drainage. Good soil drainage, frequent cultivation of the crop, and adequate fertility all help by providing favorable conditions for plant growth. Cultivating the crop while dew or rain is still on the foliage is not advisable. In districts where perennial Egyptian onions are the source of the fungus in the spring, emphasis should be given to the eradication of such garden plantings in the vicinity of extensive onion acreages.

LEAF MOLD

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by *Stemphylium botryosum* Wallr., a secondary fungus, which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly follows downy mildew or purple blotch on the seed stems.

PURPLE BLOTCH

Purple blotch is a disease of leaves, seed stems, and bulbs. It has been confused with leaf mold because the leaf mold organism commonly follows the purple blotch fungus as a secondary invader. However, unlike the leaf mold organism, the purple blotch fungus is capable of invading the onion plant quite independently of any forerunner. The disease is of some importance on the seed crop and sometimes causes appreciable losses as a bulb rot. The causal organism appears to be rather widespread in occurrence.

Characteristics

The disease appears first as small, whitish, sunken lesions with purple centers that rapidly enlarge and eventually girdle the leaf or seed stem. About 2 or 3 weeks after its first appearance, darkened zones, consisting of superficial masses of fungus spores, appear on the lesion. Usually the affected leaves or stems fall over and die within 3 or 4 weeks after lesions appear if the environment is favorable for disease development. Purple blotch requires less humid weather than downy mildew; thus it is much less limited in geographic distribution.

The bulbs are attacked at harvesttime. The fungus invades most commonly through the neck, but it may invade wounds on the fleshy scales. The decay is at first semiwatery and is especially conspicuous because of the color associated with it. The parasite secretes in abundance a pigment which diffuses through the scale tissues somewhat in advance of the fungus threads. Affected tissue is deep yellow at first, but it turns gradually to a wine red. With the profuse development of dark-colored fungus threads, the older decayed tissue eventually becomes dark brown to black. As the tissue becomes desiccated, the diseased scales eventually dry down to a papery texture. Often only one or two outer scales are affected; in other instances, notably with white bottom sets, the entire bulb may be destroyed.

Causal Organism

The causal fungus (*Alternaria porri* (Ell.) Cif.) is closely related to that associated with early blight of potato and tomato. It is confined, however, to onion and possibly such closely related plants as leek and chive. The spores, which are produced on short fruiting branches on the surface of the decayed leaves, stems, and scales, are many-celled, dark-colored, and capable of withstanding unfavorable environment; thus they carry the fungus through northern winters or hot southern summers. They germinate to produce fungus threads (mycelium) that invade the stomates of leaves and stems and wounds on the bulbs.

Control

No satisfactory control measures for the disease on leaves and stems have been devised. The practices described for the control of neck rot (p. 20) are recommended for the bulb rot.

PINK ROOT

Pink root is serious in the Delta district of the lower Sacramento and San Joaquin Valleys of California, in the Rio Grande Valley of

Figure 7.—Onion plant affected with fusarium rot. This rot begins at the base of the scales and causes the leaves to die back from the tips.

Texas, and in muck districts of New York, Ohio, Indiana, and Michigan.

The symptoms become manifest in the seedbed or after the seedlings are transplanted. Affected roots shrivel and die, meanwhile taking on a distinctly pink color. Abnormal yellowing of the roots is commonly associated with pink root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots, they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and although the affected plants are commonly not killed by the disease, the reduced food supply results in the formation of mere scallions, or small bulbs. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvesttime in the small size of the bulbs; the size varies with the severity of the attack.

The fungus which causes pink root (*Pyrenochaeta terrestris* Gorenz et al.) lives and multiplies in the soil; consequently, it becomes more destructive the longer the onions are grown in the same field. It is disseminated on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic, and a large number of unrelated economic plants.

Scientists in the United States Department of Agriculture and at several State agricultural experiment stations are working to develop the pink-root resistant varieties. Several varieties for use in winter onion growing in the South are now available. These include Excel, L–36, and Granex, which are of the Yellow Bermuda type (see p. 2); and Eclipse, L–365, Early Crystal 281, and White Granex, which are of the Crystal Wax type. Sweet Spanish No. 2, a resistant selection from Sweet Spanish, is adapted to northern onion-growing sections.

FUSARIUM ROT

Fusarium rot is a widespread disease, but it seldom causes severe losses. In the Rocky Mountain irrigated valleys it sometimes reaches economic proportions.

Rapid dying back of leaves from the tips when plants are approaching maturity is

the first evidence of the trouble (fig. 7). Most of the roots are eventually rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and when they are cut a semiwatery decay is found, advancing from the base of the scales upward. The rot progresses somewhat slowly, and many recent infections are unnoticed at harvesttime. Thus the disease becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

The causal fungi (*Fusarium* spp.) live in the soil. Infection of the plants is sometimes correlated with maggot injury. Invasion occurs through wounds or in the vicinity of old root scars at the base of the bulb. The disease is favored by high soil temperatures, which is probably the chief reason for its appearance in the Northern States after midseason and for its more common destructiveness in the western valleys, where high temperatures are not unusual.

Careful sorting at harvest is recommended. Rotation is necessary when this disease becomes troublesome.

RUSTS

Two distinct rusts have been noted in North America upon the Egyptian onion. One, caused by the fungus *Puccinia porri* (Sow.) Wint., has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus rust fungus (*Puccinia asparagi* DC.), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears before midseason on leaves and seed stems as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or aecia, eventually split the skin and expose the golden-yellow rust spores. In the case of the second disease a species of *Botrytis*, very similar to or identical with one of those causing neck rot of onion (p. 20), commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named rust is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE ROT

White rot, a disease serious on onion, garlic, shallot, and leek, has been reported in northeastern Oregon, near Norfolk, Va., near Louisville, Ky., and in Louisiana. It is known to be widespread in Europe, where it is very destructive on onion and leek in the British Isles and on garlic in Italy and Spain.

Usually white rot appears first during the cool, moist weather in the spring and fall. The first signs are yellowing and wilting of the leaves, followed later by a total collapse of the top. The causal fungus (*Sclerotium cepivorum* Berk.), which inhabits the soil, actually invades the roots and the basal parts of the bulb scales (fig. 8). If diseased plants are gently pulled, they will come up very readily, because the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a white fluffy mass of fungus threads. Somewhat later this fungus mass takes on the appearance of a closely fitting weft in which are embedded numerous black spherical bodies, or

Figure 8.—White rot on an onion plant grown in infested soil. Note that the entire root system has been destroyed and that the bases of the scales are also affected. The small, spherical, black, kernellike masses, or sclerotia, which develop upon the diseased tissue are characteristic. As a result of the destruction of the basal part of the plant the top turns yellow and gradually dies.

sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages white rot might easily be confused with fusarium rot (p. 12), but in the latter no black sclerotia are ever formed. In the later stages white rot may be mistaken for neck rot (p. 20), in which black sclerotia are commonly formed. The neck rot sclerotia, however, are several times as large as those of the white rot fungus; moreover, a gray mold is commonly associated with neck rot, while the mold associated with white rot is distinctly white. Neck rot almost always appears after harvest and starts in most cases at the neck. White rot commonly appears on the growing crop, and infection occurs in the roots and bases of the scales.

The fungus that causes white rot is disseminated chiefly by bulbs that have come from diseased soil. Once established, the parasite may persist in the soil indefinitely and is known to survive northern winters. Bulbs from a diseased field should never be used for propagation.

In Europe the disease is controlled by coating onion seed with calomel before planting. In the Southern United States where the disease is severe only on set-propagated-shallots, the only economical control devised so far is early planting of the crop.

YELLOW DWARF

Yellow dwarf was first recognized in a destructive form in 1928 in the Pleasant Valley district, Iowa, where it is said to have caused a 25-percent loss. It occurred to some extent in that district in 1927 and since then has been found in a few other States. It is most serious on the crop grown from onion sets and on seed plants. The outstanding symptoms are severe stunting of the plants and in seed plants dwarfing and twisting of the seed stems. The affected leaves and stems change from their normal green to various degrees of yellowing, extending from a few streaks to almost complete yellowing.

Yellow dwarf is a virus disease, which means that it is transmissible and infectious, but the contagious entity, or virus, is ultramicroscopic and not a bacterium or fungus. The virus persists in bulbs of infected plants. When such bulbs or sets are planted, the plants are diseased the next year and contain the virus throughout

the leaves. The virus is then carried to surrounding healthy plants by plant lice, and thus the contagion may spread rapidly during the growing season. Yellow dwarf is not serious where the crop is grown from seed only, since the virus is not carried in the seed. Where bulbs are carried over as sets or for the propagation of seed in proximity to onions from seed there is opportunity for continual carry-over and propagation of the virus. It is under such conditions that yellow dwarf has become very serious.

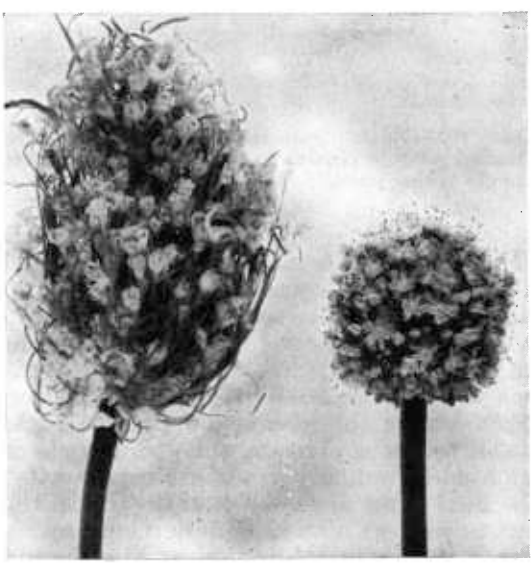
Onion sets and bulbs used for seed production should not be grown in proximity to a bulb crop grown from sets of the previous year or to a seed crop. In this way carryover of the virus is limited. Onion sets can be indexed in the greenhouse during the winter months for the presence of the yellow dwarf virus.

It is now recognized that there is more than one strain of the yellow dwarf virus, and these may differ in their virulence on onion and related plants. The Sweet Spanish variety is highly resistant to the commonly occurring strain.

ASTER YELLOWS

Aster yellows is a virus disease transmitted by the aster leafhopper, which affects many wild and cultivated plants, including such important ones as carrot, lettuce, celery, and aster. When leafhoppers carrying the virus feed upon onion and the onion becomes affected, the flower umbel takes on an abnormal appearance. The pedicels, to which the flowers are attached, become much longer than normal, and the flower is distorted and usually sterile, with the result that a corresponding seed loss is sustained (fig. 9). This disease has been noted in Idaho and Wisconsin and will probably be found elsewhere, since the aster yellows virus is widespread. Whether the damage that aster yellows causes will raise it to a major disease in some sections remains to be determined. In any case it is well to avoid planting onion seed fields in areas adjacent to such susceptible crops as carrot and lettuce.

Figure 9.—**Aster yellows affecting the flower cluster of an onion plant (left). In this diseased cluster the pedicels, to which the flowers are attached, are abnormally long, the parts of each flower are distorted, and the cluster is completely sterile. Sometimes part of the flowers in a cluster are diseased and the rest normal. In the cluster at the right the flowers are developing and opening normally.**



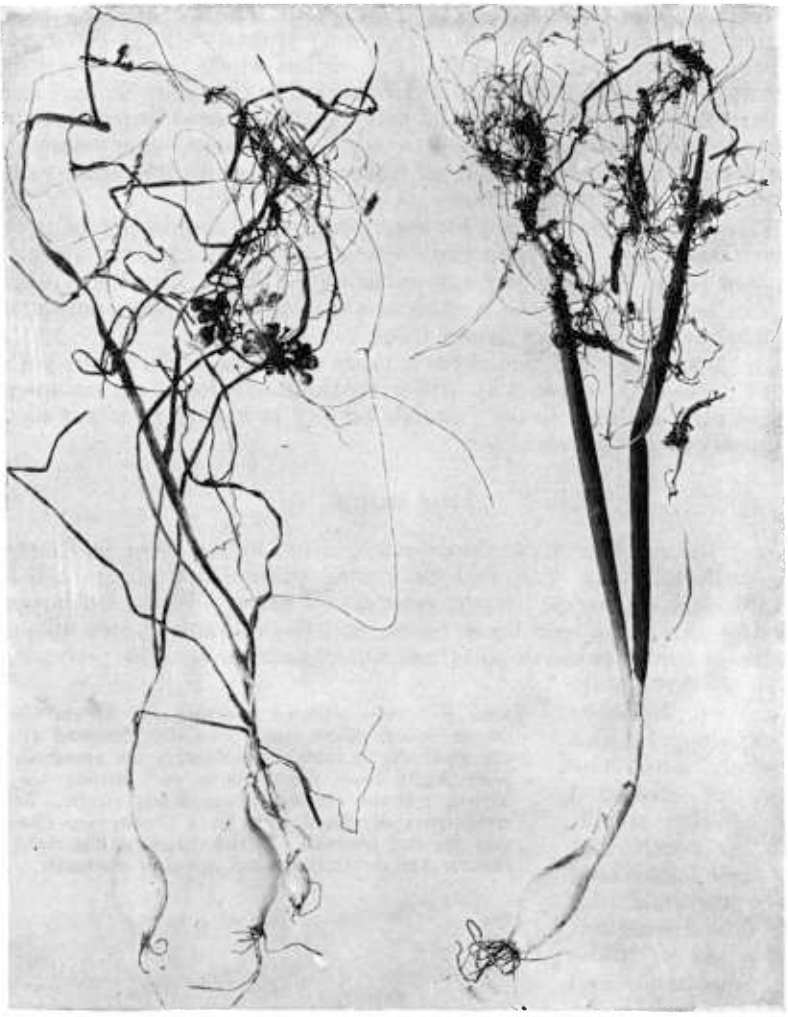


Figure 10.—Onion plants attacked by dodder, a parasitic flowering plant. This leafless parasite obtains its food by sending suckers into onion leaves and eventually killing them.

DODDER INJURY

Dodder (*Cuscuta* sp.) belongs to the higher plants and differs from the previously mentioned parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil and germinate in the spring. The young dodder plant thus starts growing just as the onion seedling does. It has no leaves, and its tendrillike stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue (fig. 10). After having thus become established as a parasite, the dodder gets most of its food from the onion and gradually sends out its tendrils to attack nearby plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers, and by the end of the season there may

occur roughly circular areas of considerable size in which the onion tops have been completely killed. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed. Dodder injury has been noted on onions in California, Washington, Illinois, and Wisconsin, and, doubtless, it is likely to occur in any onion district.

ROOT KNOT

Root knot of onion is caused by an eelworm, or nematode. The disease may be recognized by the spherical swellings or enlargements of affected roots, as shown in figure 11. The above-ground parts of badly diseased plants are dwarfed, the leaves have a sickly pale-green color, and the bulbs are reduced in size. Root knot, while occurring as a serious trouble of many wild and cultivated plants in the southern part of the United States, has been reported only occasionally on onions, and fortunately there is little likelihood that it will ever be a major disease of this crop. The minute causal nematode, which belongs to the genus *Meloidogyne*, lives in the soil, penetrates the onion roots, and produces swellings. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvae), thus completing the life cycle.

Figure 11.—Onion root knot, caused by an eelworm. Note on certain roots spherical or irregular swellings, from some of which small dark masses (the eggs) are protruding. Many active larvae of the eelworm escape from these egg masses into the soil and render it unfit for growing onions as well as many other crops.

EELWORM ROT, OR BLOAT

A strain of the eelworm, or bulb nematode (*Ditylenchus dipsaci* (Kühn) Filipj.), which occurs on hyacinth and tulip is also found on onion. It occurs particularly on muck in New York. The causal nematodes live over in onion refuse. They may attack young seedlings, causing distorted growth and death. On older plants stunting and a flaccid condition of the leaves occur. As the bulbs develop, nematodes invading the scales cause the tissue to take on a soft mealy appearance and eventually the onions decay. Control of this disease involves fumigation of the infested soil with chloropicrin or a similar fumigant found effective in nematode control.

These chemicals should be handled carefully and applied as recommended by the manufacturer.

FARM AND HANDLING PRACTICES RELATED TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth and, on going into its dormant state, becomes more susceptible to the attack of storage rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant, the bulbs must be allowed to sweat, or cure, preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture that is given off. Thus, if the weather remains clear and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of fungi and bacteria and at the same time delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck rot (p. 20) and bacterial soft rot (p. 21), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates; such accumulation favors the development of decay.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck rot (p. 20), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest, or the field should be plowed promptly. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not used for growing onions.

HARVESTING

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly, it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may post-

pone ripening and tend to cause an overproduction of scallions, or stiff necks. These should not be placed in storage, but should be sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms that cause decay. The milling of sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvesttime to throw out all bulbs that show any signs of disease or insect injury. Although smut (p. 4) and downy mildew (p. 8) fungi do not themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage-rot organisms. Fusarium rot (p. 12), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather bacterial soft rot and neck rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvesttime.

CURING AND STORING

In northern sections where the crop is likely to encounter moist weather during the harvest period, it has become generally recognized that thorough and prompt curing of the bulbs is extremely important. Since onions in this area are commonly held in storage for distribution during winter months, well-insulated storage houses are essential. Modern storages are also provided with a forced ventilating system wherein air is introduced at frequent intervals beneath bins in which bulbs are usually stored in bulk. Provision is made whereby air can be heated, if necessary. With this system, the usual practice is to bring bulbs into storage directly from harvest and begin air circulation at once. This procedure is continued for several days until the outer scales and the neck tissue are thoroughly dry. If this curing procedure is carried out promptly and thoroughly, incipient infections of neck rot (p. 20) and bacterial soft rot (p. 21) are permanently checked and progress of smudge (p. 23) on white varieties is greatly reduced. Once the onions are well cured, only infrequent air circulation is necessary to maintain proper temperature and humidity. The best storage temperature is 32° to 35° F. and the best relative humidity is 70 to 75 percent.

When the facilities described above are not available, the curing is best carried out in slatted crates which are piled in open sheds where they are protected from rain but arranged so as to take advantage of drying air currents. Bulbs so cured should not be stored in bulk but should remain in crates so that ventilation of the warehouse by natural air currents is most effective. Trapdoors are usually provided at frequent intervals along the bases of sidewalls of the warehouse, which may be opened during periods of low outdoor humidity so as to create air currents which rise in the warehouse and carry humid air out through vents in the roof. Onion sets are generally stored in this manner.

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where globe onions are grown most extensively, colored varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck rot and smudge, and handling them successfully requires much more care during harvest and curing. In the onion-set-growing sections the same is true of the White Portugal, as compared with the Red Wethersfield and Yellow Globe Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion districts of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest because of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Red Creole variety is a favorite because it resists the attacks of fungi and bacteria in storage and in transit much more effectively than the white and yellow Bermuda varieties.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK ROT

Neck rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 percent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties.

Characteristics

Usually there is little or no evidence of neck rot up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck and more rarely at the base or at a wound.

Figure 12.—Onion bulb affected with neck rot, showing softening and shriveling of the scales which begin at the neck of the bulb. Note the black kernellike masses, or sclerotia, on the surface.

There is a definite margin between the healthy and diseased tissue, the latter taking on a sunken, water-soaked appearance. A gray, feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 12 and 13). On red and yellow onions the pigment of the diseased parts is destroyed; in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several

months often elapsing before the entire bulb is destroyed. The white varieties are infected most readily, while the colored types more often escape the disease.

Figure 13.—Longitudinal section of an onion bulb affected with neck rot. Note that the outer scales are badly rotted but that the disease is just appearing on the inner scales.

Causal Organisms

Neck rot is caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds that attack lettuce, cabbage, and numerous other vegetables. These fungi are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion but require wounds in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the causal fungi, which are especially adapted to dissemination by air currents. They are thus carried to the healthy bulbs, where they germinate and send fungus threads into the necks, either through the dead tops or through wounds left by the removal of tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black sclerotia are compact masses of fungus threads, which, being resistant to cold and drought, carry the organisms over winter.

Control

As already pointed out on pages 18 and 19, the handling of the crop at harvest is particularly important in northern sections of the United States where rainy periods are likely to occur. Neck rot is of little importance in those western areas where the crop normally matures in continuously dry climate. Since infection by the neck-rot fungi takes place in the field as the plant matures, a large percentage of the bulbs may be infected without showing signs of disease as they are harvested. Experiments have shown that if the neck tissue is dried out very promptly at that time, the fungus is permanently checked and no rot will appear. This is one of the reasons why curing of bulbs by forced ventilation in the warehouse has proved to be very effective, and much more reliable than natural curing. Since bulbs of white varieties are very susceptible to neck rot they should not be stored in northern sections without artificial curing.

BACTERIAL SOFT ROT

Bacterial soft rot usually begins at the neck of the bulb, and advances down one or more scales (fig. 14). It sometimes starts in bulbs in the field slightly before harvest. At first the tissue is water-soaked; later it disintegrates into a soft, slimy mass. An offensive sulfurous odor is usually given off; this characteristic distinguishes bacterial soft

Figure 14.—Section through an onion bulb affected with bacterial soft rot. Beginning at the neck, the tissue is water-soaked and later becomes soft and slimy, giving rise to an offensive sulfurous odor. The rot advances down the scales that happen to become infected at the neck, but it does not spread readily from scale to scale.

rot from other bulb rots. The decay does not spread readily from scale to scale. It may start at bruises or wounds on the scales and commonly follows in tissue injured by freezing. When the rot affects only one or two inner scales, as is often the case, the only external sign of the disease is the lack of firmness of the bulb and often the appearance of a watery exudate through the neck when pressure is applied to the upper part of the surface of the bulb.

Soft rot differs from neck rot in that it is caused by a bacterial organism (*Erwinia carotovora* (L. R. Jones) Holland) rather than a fungus. The organism enters only through wounds and in moist environment. Onion maggots may carry the bacteria and through their feeding on bulbs provide the necessary wounds for infection. The bacteria may persist in the intestinal tract of the larvae and the adult fly and thus be carried from place to place. The eggs may be contaminated when laid by the fly, and thus the soft rot bacteria become identified closely with the life history of the maggot, depending upon the latter for its perpetuation and dissemination.

The precautionary measures already recommended on pages 18 and 19 regarding harvesting, curing, and storing should be followed carefully.

BLACK MOLD

Black mold occurs to some extent in northern onion districts, but it is of slight economic importance there. In Louisiana, Texas, and California, however, it is one of the most important storage and transit diseases.

Because of its resemblance in appearance to onion smut, black mold is often confused with it by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black mold are borne on the exterior of the scales and can be rubbed off readily (fig. 15). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it. All varieties are susceptible

but Australian Brown is usually the most commonly and seriously affected.

The causal organism (*Aspergillus niger* v. Tiegh.) is a very common saprophyte, living on almost any dead or dying vegetable matter. Where it is most serious on onions it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but it is not noticeable until the onions are pulled. Rainy weather at this critical period will result in widespread infection, which continues to develop in storage and transit.

To hold black mold in check, general sanitary measures and protection from moisture after harvest are essential. Bulbs should be thoroughly dry before being shipped, since moisture in the pack favors rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage, in order to hold the disease in check.

Figure 15.—Onion bulb affected with black mold, showing irregular sooty masses on the outside of the scales or between them. The outer scales shrivel about the neck of the bulb and assume a brittle, papery texture. Compare with onion smut (p. 4).

Figure 16.—Onion bulb affected with smudge. Note the black smudgy spots made up of small black dots on the outer scales.

SMUDGE

Onion smudge is confined largely to white varieties. It appears in the field just before harvesttime and continues to develop during the storage period. It is characterized by small, dark-green to black dots, which appear on the outer scales. These small dots may be grouped together in various ways, often in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (fig. 16). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, the chief damage being the reduction of the market quality of the crop. However, after rainy

weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

The causal fungus (*Colletotrichum circinans* (Berk.) Vogl.) lives over between seasons on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown in the same fields year after year. It is widely distributed through the trade on white onion sets and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced (fig. 16). These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

Susceptibility to this disease and to neck rot has caused a great reduction in the acreage of white varieties in northern districts. Special care at harvesttime is necessary in handling them. The crop must be harvested promptly, exposure to rain should be avoided if possible, and the curing should be rapid and thorough. Artificial curing is helpful, but it is seldom necessary except with onion sets in which neck rot also threatens to develop.

DIPLODIA ROT

So far diplodia rot has been found only on Texas-grown Crystal Wax onions. Colored onions from the same section do not show the disease, and there is reason to believe that they are highly resistant. The disease consists of a silvery-gray to black discoloration of the dry outer scales, usually on the upper half of the bulb. Parts of fleshy scales which are drying down may be affected and become black and leathery. Firm, succulent scales are not attacked. The discoloration is due mainly to the threads of the causal fungus (*Diplodia natalensis* P. Evans) on the surface of the outer scales and between them and the next inner scale. Black pin-point bodies (pycnidia), which contain the spores of the fungus, appear later. The damage is chiefly that of a blemish. The fungus attacks other crops, including citrus fruits.

ASPERGILLUS ROT

Aspergillus rot is a decay of garlic bulbs, which has been found twice on imported stock. The scales are reduced to a rather dry powdery condition, and brown kernels (sclerotia) two or three times the size of the head of a pin occur throughout the mass. The causal fungus (*Aspergillus alliaceus* Thom and Church) commonly fruits on the surface as a lemon-yellow mold similar except in color to black mold. The fungus, though never yet found naturally on the onion, can readily decay onion bulbs if it gains entrance through wounds. The sclerotia are somewhat larger and browner than those of the white rot organism and smaller than those of the neck rot fungi. Attention is called to its occurrence, since it is likely to be found on the onion at some future time. The parasite works only at somewhat high summer temperatures and thus will cause a serious rot in cold storage.

BLUE MOLD ROT

Blue mold rot occasionally affects onion bulbs and more often those of garlic. Light-yellowish lesions first appear on the fleshy scales and as the decay progresses a fine white surface mold becomes visible. The formation of bluish-green spores in mass on the surface mold soon follows, giving the characteristic blue mold symptoms. This disease may proceed within the cloves of garlic and convert the tissue to a greenish-tan or gray powdery mass without external evidence of decay other than the decided loss in weight of the bulb.

NONPARASITIC BLEMISHES AND MALADIES

FREEZING INJURY

Occasionally onions are subjected to freezing temperatures. Growing plants may be killed if the temperature is low enough and lasts long enough. The Bermuda and Sweet Spanish varieties are much more susceptible than the Globe varieties. The first-named types are also more likely to show a larger percentage of doubles and multipliers among the plants that survive freezing in the field.

Bulbs exposed to freezing temperatures in the field, in storage, or in transit will show freezing injury. The average freezing temperature for onions of the globe type is about 30° F. It is possible to cool them below the freezing point without injuring them. If they are handled or moved in the undercooled condition, ice forms in the tissues and damage sets in. Undercooled bulbs suffer less damage if they are thawed out at 50° or above than if thawed slowly at 32°.

Freezing injury can be determined by cutting the bulb longitudinally or transversely. The affected tissue is water-soaked, discolored, and more or less transparent, having indefinitely scattered opaque areas. Freezing injury is easily confused with physiological breakdown. It is not uncommon to find some scales injured and others not, because the freezing point of the tissue varies. Thus the outer scale may be injured, the next one sound, the third injured, the next sound, and so on. Soft rot commonly follows the freezing injury. If the latter is confined to the outer scales, the bulbs can usually be salvaged by being spread in thin layers and allowed to dry out.

SUNSCALD

When onions are harvested under conditions of high temperature and very bright sunlight, scalding of the tissue exposed to the sun may occur. Immature uncured bulbs are more subject to injury since the succulent tissue is more likely to be exposed. The damaged tissue, usually in areas up to 2 inches in diameter, appears bleached and becomes soft and slippery. This tissue loses water rapidly and when it dries down becomes a disfiguring blemish. However, decay-producing organisms, principally the bacterial soft rot organism, commonly gain entrance while the injured tissue is still succulent and greater damage follows. Sunscald can be prevented in districts subject to the damage by protecting the bulbs from direct exposure to the sun during curing. One method is to pull the onion with tops intact and lay bunches in windrows so that the tops of each bunch will cover the bulbs of the previous bunch.

Greening of bulbs by the formation of chlorophyll in the outer fleshy scale may occur if onions are allowed to cure too long in moderate light. This sometimes causes an unpalatable taste, but no shrinkage or decay. It can be avoided by removing the stock to dark storage as soon as sufficient curing has proceeded in open sheds or outdoor piles.

PHYSIOLOGICAL BREAKDOWNS

Physiological breakdown of onion, an injury not unlike freezing injury in symptoms, sometimes develops after harvest in bulbs that have not been exposed to low temperatures. The scale tissue is discolored and water-soaked; and, though more common on scales near the surface, it may be found on deeper ones. The nature and cause of this injury are not known. It may be found in the market and in storage and may continue to develop during the storage period. For this reason it is likely to be confused with freezing injury, and it is therefore advisable to know the history of lots in question before final diagnosis is made.

In garlic a physiological breakdown, commonly known as waxy breakdown, sometimes occurs in the outer cloves of garlic bulbs. Small, slightly sunken, light-yellow areas appear in the clove tissue, turning gradually to a deep-yellow amber color throughout the clove. The tissue thus becomes translucent and sticky or waxy, but not soft. The breakdown is usually obscured by the unaffected, dry outer scale until a late stage, when shrinkage and the amber-brown color become visible through the outer scale. The conditions which favor waxy breakdown are not known.

CHEMICAL INJURIES

Blemishes of market onions, which reduce their attractiveness, are commonly encountered, especially in colored varieties. The color compounds in the scales are in the same general class as the chemist's color indicators, and therefore they respond accordingly to changes in acidity or alkalinity. A number of color blemishes occur that are caused by contact with alkaline materials. One of the most common of these is alkali scorch, or bag print. Dark-brown to black spots on yellow or red onions occur at points at which the bulbs come in contact with the jute-bag container, particularly if the bag has become moistened after being packed. Alkaline materials infiltrated in some bags are responsible for this. They occur in some lots of bags and not in others.

Another reaction of the same type is sometimes encountered in cold storage, where leakage of ammonia fumes results in alkaline reaction of moisture on the surface of colored bulbs. Less than 1 percent of ammonia in the storage-room air will cause marked discoloration. A similar effect has been noted on stock covered with manure for protection from frost, in which case ammonia fumes arise from the manure. In all these cases the strength of the material, the amount of moisture on the bulb surface, and the duration of the exposure determine the extent of the injury.

U. S. GOVERNMENT PRINTING OFFICE: 1959

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 15 cents